Royal Commission

on

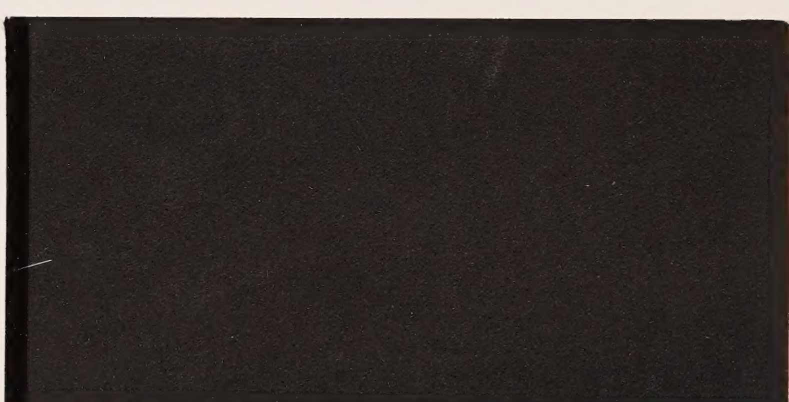
Electric Power Planning

CONVENTIONAL AND ALTERNATE

GENERATION TECHNOLOGY

ISSUE PAPER # 3 JANUARY 1977

Ontario



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Introduction

In its most simplistic form the central purpose of the Royal Commission on Electric Power Planning can be expressed in a single sentence - "To identify a long-term electric power strategy for Ontario and to consider its implications." The word "strategy" is used in the sense of the development of "planning concepts". And central among the basic requirements in developing any energy strategy is a consideration of the primary fuel needs. In particular, the question arises - what primary fuels should be used to generate electric power in Ontario taking into account economic, financial, environmental, lifestyle, health, and fuel availability factors?

This issue paper, third in the series, will consider the issues relating to the so-called conventional methods of generating electricity, projected into the future, and the issues relating to what have come to be described as "alternate energy sources" and especially their potential utilization in space and water heating and in the generation of electric power. Conventional generating technologies will be considered under two main headings, (a) hydraulic generation, (b) thermal generation - coal, oil, natural gas and recycled waste.

The alternate generation technologies will be considered under the headings of (a) multi-purpose plants, (b) solar energy, and (c) other potentially viable electric power generation systems which may be commercially available by the end of the century (e.g. nuclear fusion; magneto-hydrodynamics; wind power; biomass). The issues relating to nuclear fission power in Ontario were identified and explained in the Commission's first issue paper.

In any discussion of electric power generation it is important to differentiate between 'base load generation' and "peak load generation". Base load generation can be defined as "generation which operates, or is capable of operating, at full output most of the time it is available", while peak load generation is "generation whose power output is produced chiefly during the daily peak load periods - at other times of the day it is normally shut down or operated at minimum safe loadings". Base load power is normally provided by generating stations with comparatively low or virtually zero fuel costs (e.g. nuclear power and hydroelectric power), while peaking power generators, which supplement the base load generators, and which are comparatively costly to operate, must be capable of supplying a comparatively rapidly changing demand (i.e. the load) especially during peak periods. Peaking generators are rapid start-up and rapid response generators (e.g. oil, gas, and coal-fired generating stations and diesel generators). Note that fossil-fired generators can act as base load stations although for economic reasons this may not be desirable over long periods, while hydroelectric generating stations can act in a peaking capacity.

Since 1951, when the R.L. Hearn coal-burning station was put into service to supplement the then exclusively hydroelectric based system, there has been no doubt that the electric power system in Ontario should incorporate a mix of generating technologies. This continues to be the policy of Ontario Hydro.

Primary fuels are said to be either renewable (hydroelectric energy, direct solar energy, wind energy, biomass energy, etc.) or non-renewable (i.e. fossil fuels, uranium, thorium and subsequently, if nuclear fusion power becomes a commercial reality, deuterium and lithium). The current global energy debate is concerned essentially with the rate of depletion of the non-renewable fuels (especially oil and natural gas) and with the extent to which these fuels can be replaced by renewable sources of energy or by long-term non-renewable sources such as nuclear fission and fusion. Be it noted, and emphasized, that energy cannot be recycled (like many materials) - once burned, a lump

of coal, or a pint of gasoline, has gone for ever (see page 4 also).

It is fascinating to note that, with the possible exception of nuclear power (it has been suggested that the uranium and thorium deposits on earth may have originated, several billion years ago, in the centre core of a star), all energy used on earth ultimately comes/or came from the sun. Accordingly, solar energy, in the form of direct radiant energy, ultimately gives rise to the winds, hydro-power and biomass; while during the course of long-term geological processes, over many millions of years, coal, oil and gas deposits are formed - originally these were the products of photosynthesis giving rise to the growth of vegetation which subsequently decayed.

This paper will not be concerned so much with the technological issues which relate to various methods of generating electricity, although some basic physical laws are introduced, as with the socio-economic issues associated with them. In particular, such issues as the security of fuel supplies, the siting of generating stations, environmental and health factors, and other socio-economic factors will be introduced. But before considering specific generating processes and their implications it may be helpful to introduce briefly the basic concepts of "energy conversion" and "energy storage". Both concepts are central, for example, to an understanding of the generation of electric power and the potential role of solar energy in electric power planning.

I. Energy Conversion and Storage

All energy systems are predicated on the basic laws of physics, and, in particular, the laws of thermodynamics establish the fundamental principles of operation of these systems. Although it's not necessary for most of us to understand these laws in depth, unless we are designers of energy generating facilities or research workers in the energy field, or teachers giving courses on energy, it is nevertheless important for all of us to know that the technology of electric power generation

is founded on basic physical laws which have withstood the test of time. These laws explain, for example, why the efficiency of thermal generating stations (both nuclear and fossil-fueled), in spite of excellence in design, is always comparatively low if they are used solely for the generation of electricity. However, if thermal generating stations are used for the co-generation of electricity and thermal energy (e.g. for district heating) application of the basic laws indicates that it may be possible to improve the overall efficiency of utilization of the primary fuels.

There are two laws of thermodynamics and they are vitally important in any meaningful discussion of energy and its utilization. A simple statement of them may not be out of place in this paper. The first law states, quite simply, that energy can neither be created nor destroyed although it can change its form - e.g. the energy in free falling water (i.e. gravitational energy) can be converted to electrical energy. The second law, in simple form, states that in all natural processes the conversion of energy, or the transfer of energy (e.g. the flow of electricity through a transmission line), is always accompanied by losses of energy - in other words it is impossible to convert completely a given quantity of energy into work. What happens is that "nature" always "gobbles up" some of the energy and this is what "entropy" is all about! This inherent loss of energy (it is sometimes erroneously referred to as waste energy - erroneously, because we can't do anything about it), for example, gives rise to the concept of the irreversibility of the combustion process. After burning a fuel it is impossible, even ideally, to collect together all the products of combustion and to "reconstitute the fuel" - we can't put "humpty-dumpty" together again! Energy cannot be recycled!

All physical and biological processes, in one form or another, embody energy conversion processes - some of the most complex known to man are, of course, involved in the conversion of food energy into "muscle power" and "brain power". And the

conversion of some of the energy stored in the nucleus of an atom of uranium-235 into electric energy is a major manifestation of man's scientific and technological skill.

It is most important to note that, whenever the process of energy conversion takes place, there is an inevitable degrading in quality of some of the energy; this is yet another manifestation of the "second law". What do we mean by "quality of energy"? - formally, we say the "quality of energy describes the degree to which energy can be converted into work". For example, some forms of energy, such as electricity and gravitational energy (the higher a weight is lifted from the ground the greater its potential energy), are high quality forms because they can almost completely be converted into work as well as into other forms of energy. On the other hand, the massive amount of thermal energy contained, for instance, in Lake Ontario is low quality energy because the temperature of the water is comparatively low. Note that high temperature sources of thermal energy are of higher quality than low temperature sources. It is an exasperating fact that many major sources of energy on earth (e.g. the thermal energy stored in oceans and lakes) are low quality sources and as such are virtually unuseable by man.

Coal, crude oil and natural gas are all high quality forms of energy, so is solar energy (from which is derived wind energy, hydraulic energy (e.g. water falls), tidal energy, wave energy, biomass energy, etc.).

As implied previously, the energy conversion process is ubiquitous. It is not only basic to the generation of electricicty but it characterizes all uses of energy. Consider the conversion of the chemical energy of gasoline into the mechanical energy of an automobile, the conversion of electric energy into audio, video, and thermal energy in a television set, etc. Being aware of the fact that energy conversion inherently involves energy losses, it behooves man to ensure that these losses are minimized by the choice, if feasible, of appropriate processes. This is one

of the most important lessons to be learned from elementary thermodynamics. It is well illustrated by a simple example.

If we boil the water in a kettle using a very hot flame, say an oxy-acetylene torch, the water will boil very quickly. But the process is very inefficient from the standpoint of primary energy utilization. Nor is it much more efficient if a gas or electric stove is used. On the other hand, if we use a large concave mirror, say two meters in diameter and made quite simply using tin or aluminium foil suitably supported, to concentrate solar energy and to direct it on to the surface of the kettle, the water will probably take longer to boil but the process is more efficient bearing in mind the fact that solar energy is "free energy". Admittedly the "solar energy" approach is by no means as convenient, at any rate today, as the electric heater. The lesson to be learned, and it is an important one, is that to ensure efficiency of utilization of energy, sources should, wherever possible, be fitted to "end-uses". This is an important manifestation of what has been called "thermodynamic-thrift", another is the whole process of energy conservation. For instance, a bicycle is a very thermodynamically thrifty device as compared with an automobile.*

We hope at this point that the term "thermodynamics" is not considered to be "scientific jargon". If we understand the simple energy conversion processes involved in boiling a kettle we are well ahead. And if further erudition is needed the reader is referred to Flanders and Swan's epic recording - "The Drop of Another Hat" - he or she will not only learn about "thermodynamics" but also about the mysteries of "entropy"!

There are many ways of storing energy, ranging from the atomic-scale storage in nucleii and the single cell, to storage, on a terrestial scale, of solar energy in the oceans. And, of course, the earth itself stores a fantastic amount of thermal energy (e.g. geothermal energy). From society's point of view

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*It has been shown that the bicycle is the most energy efficient form of transportation known to man - it is four times more efficient than walking!

the purpose of storing energy, in any form, is to ensure a continuing supply when the primary source is cut off or for economic reasons. It is a particularly important requirement in the case of solar energy and wind energy sources of power.

Fossil fuels have been stored in the earth's crust for millions of years and when extracted they can be stored in dumps or, in the case of liquids and gases, in storage tanks so that they are readily accessible for use. Mechanical energy may be stored in spinning flywheels, or by compressing springs, or air, or oil (an automobile's suspension system may be regarded as an energy storage system which cushions the effect of irregular terrains).

The storage of electricity in small amounts is comparatively simple; it is carried out using "capacitors" which in their basic form consist of two parallel plates separated by a dielectric material such as air or mica. But such a method is quite impracticable for the storage of large quantities of electricity. However, the over-all capacity of an electric power system can in fact be increased by storing energy during night-time when the demand is low, and by using the stored energy to help with day-time peak conditions. The most widely used method of carrying out this process is known as "pumped storage". Water can be pumped to a suitable height and stored in a reservoir (or air can be pumped into a large cavern), by using large electric powered pumps, and the stored energy can be released from the reservoirs when required. The storage reservoirs at Niagara are excellent examples of the technique.

The storage of electric energy may also be achieved, in effect, by using electric power to electrolyse water and to store the resulting hydrogen for future use as a gaseous fuel perhaps in combination with carbon (the gas methane is convenient for storage and for use as a fuel). It has been suggested that the large-scale production of hydrogen, utilizing excess electric generating capacity, might eventually lead to a "hydrogen economy"

- most specialists in the field agree, however, that this technology may not contribute much to Ontario's energy requirements during the present century.

The storage of electricity, on a smaller scale, is attracting a great deal of attention. For instance, if a suitable storage battery were available, at reasonable cost, it is highly probable that electric-powered automobiles and small vans would be an attractive alternative to conventional road vehicles (the batteries of these electric vehicles would be charged during "off-peak" periods).

One of the most important energy storage problems being studied at present is that of storing solar energy. In order to be a viable alternative to other space heating and water heating methods, solar energy must have associated with it an adequate means of storage probably in the form of thermal storage. This is necessary so that thermal energy will be available during the night and when there is heavy cloud cover. Technical details are beyond the scope of this issue paper, although the topic will be introduced briefly in section VI.

II. Hydraulic Generation

For almost fifty years the generation of electricity in Ontario was exclusively hydroelectric - i.e. electricity generated by the conversion, first of the kinetic energy of falling water into the mechanical energy of a hydraulic turbine rotor, and secondly, the conversion of this mechanical energy into electric energy by means of an electric generator. At present the proportion of hydroelectric generation in the total electric power system of Ontario is nearly 40%, of which about 96% is contributed by Ontario Hydro and the remainder by private companies, notably the Great Lakes Power Company.

There are some 72 hydroelectric plants operated by Ontario Hydro, these range in capacity from a fraction of a megawatt to 1,200 megawatts (MW). During the past few years several small

generating plants have been closed down because of the high cost of maintenance.

Hydroelectric plants have many advantages. For example, they operate with high capacity factors* which may be as high as 95% as compared with about 70-80% for nuclear plants, and roughly the same for large fossil-fueled generating stations. Other advantages are the low-cost of electricity generated by hydroelectric stations - these reflect the fact that the cost of fuel is virtually zero (although the province has levied water rentals in connection with hydroelectric stations this cost is not appreciable) and a large number of hydroelectric plants have already been amortized. The plants are highly reliable, highly efficient, comparatively easy to maintain and, if necessary, the hydraulic turbines can be used in reverse as hydraulic pumps which, when driven by electric motors (the generators are dual-purpose) can provide the necessary motive for "pumped storage".

On the other hand, in Ontario, there are several factors which mitigate against any appreciable expansion of the hydro-electric component of the electric power system. These are considered below under the headings, site availability, environmental factors, and socio-economic factors.

(a) Availability of sites

A hydroelectric site requires an adequate supply of water (dependent on the rainfall in the "catchment" area) and an adequate "head" (e.g. height of a water-fall). There are virtually no major potential sites remaining in Southern Ontario, although we understand that there are an appreciable number of "small" sites which may, from environmental and economic standpoints, be potentially viable. On the other hand, in Northern Ontario there are a limited number of major sites associated with the large river systems. Of the latter the Albany River system has the greatest hydroelectric potential - it has been estimated, assuming a complex system of diversions, to

* "Capacity factor" is the term used to describe the aggregate availability of a generating station - if a station has a "capacity factor" of 95% it is available 95% of the time.

have a potential average generating capacity of 2000 MW. In addition, there is a potential of 1200 MW from other river systems in Northern Ontario. The issues relating to siting are:

- The potential hydroelectric sites are large distances from the major load centres in Ontario, and there are obviously massive technical difficulties in the development of the sites because of limited transportation facilities. From the standpoint of geography and technological problems how viable is the prospect of the development of these sites?
- Several economic and technical reasons have been given for the decommissioning of some of Ontario Hydro's small hydraulic stations. In view of the changing economic climate and the advent of new technologies (e.g. for automatic control and monitoring of stations), should an in-depth reassessment of the viability of these small generating stations be undertaken?
- If, because of financial and economic constraints, there is increasing interest in some decentralization of the electric power system and in increased private ownership of generating facilities, to what extent would such developments be desirable, and to what extent would recommissioning (or commissioning) of small hydroelectric sites contribute, if at all, to the overall efficiency and reliability of the province's electric power system?

(b) Environmental factors

Hydroelectric generating plants are normally considered to be "environmentally clean". However, there are potentially serious problems in this regard. Quite apart from the negative visual environmental impact (i.e. the aesthetic impact of a dam or reservoir on an otherwise beautiful natural area), there may be safety problems associated with dams. On the positive side, however, the potential for flood control and for irrigation should also be taken into account. And also, most importantly, there are ecological issues associated with the development and operation of hydroelectric plants. The Environmental Assessment Act, and its implementation through the Environmental Assessment Board, will provide the necessary regulatory machinery to ensure

the minimization of such environmental insults. Presumably such considerations as the following will be investigated:

- The impact of hydroelectric site development on fish populations, especially on spawning beds, and on wild-life generally e.g. the migration of animals and birds.
- The effect of flooding and the creation of river diversions on land use.
- Associated with all electric power generation there are transmission lines - the environmental impact of these on wild-life, potential threats to humans, and threats to agriculture and forestry will be considered in Issue Paper #4.

It should be noted that, because of the renewable nature of hydroelectric power, the cumulative stress over time of a specific facility on the environment will probably decrease. Nature has a fantastic power of adaptation in the long-term although the short-term effects are frequently undesirable.

(c) Socio-economic factors

The main virtue of hydroelectric generation is its use of a renewable source. But there are several penalties to be paid, not least the escalating capital costs of major hydroelectric developments especially in remote areas of Northern Ontario. Furthermore, there is a negative impact of hydroelectric development on the traditional life-styles of people dwelling in the affected areas. On the other hand, there may be potential for economic development because of the availability of abundant electrical energy. On the positive side also a large-scale hydroelectric project may be useful for flood-control.

The socio-economic issues relating to hydroelectric power development, with special reference to Northern Ontario, are outlined below. It should be noted that most of these were raised during the Commission's meetings held in Northern Ontario during the last week of August 1976:

- The capital cost of developing major hydroelectric facilities in Northern Ontario is appreciably greater than the capital cost of developing coal-fired or nuclear generating stations. Can such hydroelectric schemes be justified in these circumstances albeit taking into account the fact that hydro-power is a

renewable resource?

- Assuming hydroelectric developments in Northern Ontario are economically justifiable and viable, such developments might have a profoundly negative affect on the life-styles of the native peoples of affected regions - in particular on such traditional pursuits as trapping, hunting, fishing and tribal activities because some native communities would be decimated. Can hydroelectric developments be justified in these circumstances?
- The reliability of hydroelectric plants depends on adequate rainfall and freedom from drought conditions. During the summer and fall of 1976 many of the tributaries of the great rivers in Northern Ontario were substantially reduced and such drought conditions have a habit of recurring. To what extent have federal and provincial government studies revealed potential water shortages, in for example, the water-shed of the Albany River?
- Assuming the development of hydroelectric sites in Northern Ontario were to proceed, what would be the social impact of a large influx of, for example, several thousand work people and their families from Southern Ontario? How would the required "amenities" be regarded by the Indian peoples?
- A major hydroelectric development, or series of developments in Northern Ontario, would be an inevitable step towards increased economic activities in the region especially in the pulp and paper and the mining industries - is this desirable?
- The socio-economic issues, relating to Northern Ontario, apart from the financial and technological aspects, are essentially the concern of the peoples who dwell in these regions - how much weight should be given to their desires and how much weight should be given to those of "outsiders"?

III. Thermal Generation

The thermal generation of electric power involves the conversion of thermal energy, in the form of high-pressure super-heated steam (created in boilers heated by the combustion of various non-renewable fuels of which coal, oil, natural gas, and uranium are the most common), by means of turbines and generators into electric energy.

The percentage contributions of hydroelectric, fossil-fueled, and nuclear-powered generation, together with electricity purchases, for the year 1975, and projected for the year 1980, are shown in

the table below:

TABLE I

DISTRIBUTION OF PRIMARY FUELS AND ELECTRICITY PURCHASES
USED BY ONTARIO HYDRO IN 1975 AND PROJECTIONS FOR 1980 (PERCENTAGES)

YEAR	HYDRO ELECTRIC	COAL	RESIDUAL OIL	NATURAL GAS	URANIUM	ELECTRICITY PURCHASES	TOTAL
1975	39	24	1	6	13	17	100
1980	26	34	6	3	28	3	100

It is noteworthy that while the percentage of hydroelectric generation is decreasing, that of coal-burning and nuclear power are both increasing. Reliance on these primary fuels (i.e. coal and uranium) characterizes the electric power generation picture in several industrialized nations including the U.S.A., the U.S.S.R., France, Great Britain, West Germany and Japan. The basic issue of whether to burn coal and uranium, or neither, during the short-term period up to, say, the year 2000, will probably be debated vigorously in several of these countries as well as during the debate stage of our inquiry.

In this section we will introduce and explain the issues which relate to the security of fossil fuel supplies; siting of generating stations; associated environmental and health concerns; socio-economic factors; and research and development programmes. These issues were, for the most part, introduced during the Commission's Preliminary Meetings and Information Hearings - although fairly comprehensive they should not be considered as exhaustive.

(a) Security of fuel supplies

Although Ontario has comparatively large resources of uranium, which, together with the uranium deposits in Saskatchewan and Quebec might be sufficient for Canada's nuclear fuel requirements for at least 30, and possibly 60 years, the province's indigenous fossil fuel resources are comparatively small. For example, Ontario has virtually no indigenous oil or natural gas resources and the only coal resource is the Onakawana lignite deposit in Northern Ontario with an estimated proven reserve of about 200 million tons.

Assuming a 1000 MW coal-burning generating plant requires 7 million tons of lignite per year (lignite is a comparatively low quality fuel), the total deposit in Northern Ontario would supply such a station for about 28 years.

Insofar as the supply of fossil fuels is concerned, therefore, Ontario is largely dependent upon imports of coal from the United States, at present about 7½ million tons per year, and of oil and natural gas from Western Canada. However, plans have been finalized for the consumption of between 4.0 and 6.0 million tons of Western Canadian bituminous coal per year by 1980.

The issues relating to the future supplies of fossil fuels appear to be:

- With the probable increasing demand for fossil fuels, especially in the United States, how secure are Ontario Hydro's coal needs for the period 1983-93 and beyond assuming, say, a two or three-fold increase in requirements by 1995?
- To what extent can reliance on Western Canadian coal be assured? Are present and projected coal transportation facilities adequate to cope with a three-fold increase in demand for coal?

Note that the coal to be delivered from Western Canada will cost about 50% more than the cost of contract coal delivered from the United States - note also that Ontario Hydro's existing coal-fired stations were designed specifically to burn United States' coals which differ appreciably in character from Western Canadian coals - a blend of U.S. coal and Western Canadian coal would be required for existing stations but future coal-fired stations could be designed to burn Western Canadian coal.

- How much reliance can be placed on the availability of residual oil (i.e. processed crude after removal of petro-chemical high quality products and other light oils) for the generation of electric power in Ontario in the light of dwindling domestic supplies and the escalating costs of off-shore crude oil?
- Although natural gas is not regarded, by Ontario Hydro,

as a priority fuel, to what extent could this Canadian resource be utilized for fueling existing and potential gas-fueled generators? What is the potential for dual-purpose gas-fueled generators?

- To what extent can recycled municipal wastes be used (probably in conjunction with coal) as a fuel for electric power generation? How reliable is this "resource" likely to be?

(b) Siting of generating stations

Many factors are involved in the siting of large fossil-fueled generating stations. Apart from environmental and health factors and other socio-economic factors, to be considered subsequently, the most important siting criteria appear to be:

(i) Proximity to coal transportation terminals (or to oil and gas pipelines) is essential. Note that during the winter months Great Lakes shipping is shut down and stockpiles must be provided.

(ii) All Ontario Hydro major thermal generating stations are located on the shores of the Great Lakes. These stations require large amounts of cool water to condense low temperature and low pressure steam and the Great Lakes provide an excellent "sink" for the associated discharges of low quality thermal energy . This method of operation is normally referred to as "once-through cooling using Great Lakes Water". It is theoretically possible for thermal-generating stations to be located "inland" in which case the cooling system may be based on wet or dry cooling towers or cooling ponds.

(iii) Coal-fueled stations should be located, bearing (i) and (ii) in mind, so that large quantities of fly ash can be handled and disposed of.

(iv) If in the close vicinity of urban areas, the siting of coal-fueled stations, in particular, should take into account prevailing winds, especially in winter, and the height of station chimneys should be determined accordingly.

The issues relating to the siting of fossil-fueled stations are essentially environmental and socio-economic in nature and as such will be considered later. However, there is a technologically-oriented concern which should be noted:

- In the siting of a new thermal generating station to what extent should the potential for "district-heating" be a central consideration?

(c) Environmental and health factors

The combustion of fossil fuels invariably involves the emission of a broad range of air pollutants of which the most notable are sulphur dioxide and oxides of nitrogen. In general, the air pollution due to burning oil and natural gas is appreciably less than that due to burning coal. In particular, the sulphur content of some coals makes them undesirable for electric generating purposes. The United States coal, imported by Ontario Hydro, has comparatively low sulphur content while the Western Canadian coals have even lower sulphur content. In sufficiently high concentrations sulphur dioxide can cause serious respiratory problems especially in elderly people. Furthermore, sulphur dioxide and sulphur trioxide (during rain showers this becomes "acid rain") can also cause crop damage.

The oxides of nitrogen are not only the cause of photochemical smog, which was originally detected at Los Angeles, but they are also responsible for damage to certain crops. The chemical responsible for this is the toxic gas ozone, formed by the action of sunlight on a mixture of nitrogen oxides and hydrocarbons, which can cause respiratory distress and which has also been identified as the major agent which causes widespread damage to such crops as white beans, potatoes and tobacco.

The combustion of coal, and to a lesser extent that of oil and natural gas, also gives rise to the emission of microscopic particles - the particulates. Under certain meteorological conditions both SO_2 and the particulates become trapped in stagnant air masses and may accumulate to dangerous levels.

The production of CO_2 is also characteristic of the combustion of fossil fuels - the effects of CO_2 and the particulates on long-term climatological conditions is being investigated in university and government laboratories.

In addition to the aforementioned air pollutants a range of trace elements, including lead, arsenic and some radioactive elements are also detectable. While much of the particulate matter can be removed by electrostatic precipitators, and the emission of SO_2 can be controlled by "scrubbing the flue gases" or desulphurizing the fuel, these measures are by no means 100% effective and, their costs and energy requirements may be appreciable.

What are the issues relating to the environmental and health impacts of burning fossil fuels? Those which were identified during the information hearings were:

- Are adequate steps being taken, or proposed, to minimize the environmental and health hazards associated with the burning of fossil fuels?

- If, for financial, environmental and health reasons, there were to be some slowing down of the nuclear power programme in Ontario and if as a consequence there were to be increasing emphasis on coal-fired generating stations, would the additional air pollution be acceptable to the public (especially those in affected areas)? To the farming communities?

- An ethical issue which could have significant consequences for future generations relates to CO_2 levels in the earth's upper atmosphere. These are increasing and appear to be irreversible. Future increases in the quantity of coal being burned will inevitably increase the CO_2 levels at an even faster rate. The long-range effect on world climate could be a cause for concern. Is this environmental hazard understood? Is it an acceptable "risk" bearing in mind ethical considerations? (See also Issue Paper # 1 page 10, in which the ethical issues relating to nuclear power are introduced.)

- Although peripheral to the Commission's Terms of Reference, any consideration of coal as a primary fuel for the generation of electric power should

include the environmental and health hazards associated with coal mining. To what extent should these factors be taken into account in weighing the respective advantages and disadvantages of the conventional and alternative methods of generating electric power? (Note that a similar issue, which was inadvertently omitted from Issue Paper # 1, relates to the mining of uranium - see for example, the report of the Ontario Royal Commission on the Health and Safety of Workers in Mines.)

(d) Socio-economic factors

The social consequences which arise from the development of energy resources although often localized (e.g. the mining of coal and uranium, and the construction of large electric generating plants) also affect the whole fabric of society. On one hand are the beneficial uses to which energy is put - houses are made more comfortable, tedious domestic chores are reduced, manual labour in industry is minimized, the mobility of the population is considerably increased, etc. But, on the other hand, we have noted the negative consequences of increasing energy consumption. A key issue, which might have been included in Issue Paper # 2, can be summed up in the question: Is there any indication that the rise in energy consumption, of all forms, has been matched by a corresponding increase in human well-being?

Although the capital cost, per kilowatt, of coal-fired generation stations is less than that of nuclear and hydroelectric power stations of equivalent size, fossil-fueled generating stations are more costly to operate and there is an increasing likelihood of further increases in fuel costs. Furthermore, the capital and operating costs of coal mining, and its energy intensive nature, should also be borne in mind. Reference has already been made to the transportation problems associated with coal-burning generating stations - here again costs may increase.

The following socio-economic issues are additional to those which have already been identified in Issue Paper # 2 - others, especially those relating to financial matters, will be introduced in a subsequent issue paper:

- Taking into account the relevant economic, financial, and environmental factors how can the social costs and benefits of alternative methods of generating electric power be evaluated? Using what criteria? How might these be weighted?

- In the cases of new thermal generating stations how should the conflicting interests of agriculture, recreational potential and electric power production, insofar as the siting of stations is concerned, be resolved?

- The contruction and operation of large thermal generating stations (also hydroelectric stations) have an impact on neighbouring communities in many ways. These are described in Ontario Hydro's Memorandam on "Socio-Economic Factors" page 4.2-1. Community impact studies are being undertaken in connection with these impacts - are these considered to be adequate? Is the local community adequately represented in decisions relating to the social and economic changes resulting from the construction and operation of generating facilities?

- It has been claimed that large-scale construction projects such as thermal generating stations can put new economic life into a community. However, the counter-argument has been raised to the effect that in the long-term there may even be an increase in unemployment in the area after the completion of the project. What evidence is available to support each of these arguments?

(e) Research and development

There are many comprehensive research and development programmes being undertaken on a global basis in connection with the thermal generation of electric power because of the unique position it occupies as an energy resource. It is not surprising, therefore, that R & D programmes, especially in the United States, concerned with the combustion and utilization of coal are being expanded. For example, the fact that coal is a comparatively dirty and

inconvenient fuel to use is spurring the development of processes to convert coal into synthetic natural gas and liquid fuels. These may be significant in the generation of electric power by the end of the century. The major problem at present appears to be the high cost of producing synthetic fuels.

Research in the combustion process itself, with special reference to the separation out of air pollutants, is extremely important. Although the process known as fluidized bed combustion has been well known for many years its implementation on a commercial scale has been slow in North America, compared, for example, with some European countries. In this process the sulphur is retained in the "bed" as solid waste.

There has been increasing interest during the past few years in the utilization of municipal wastes as a fuel - the "watts from waste" concept. The idea is to generate electric power by burning municipal wastes usually in combination with coal. Ontario Hydro is participating in such a development, and a demonstration unit is being installed at the Lakeview Generating Station. The unit will be operational within the next 12 months (its capacity is about 100,000 tons of refuse fuel per year). The major problems relate respectively to the separation of combustible materials, and to the design of furnaces and boilers to withstand higher levels of corrosion than are normally experienced. Note that the process can be thought of as "recycling waste".

There are several comprehensive research programmes being undertaken in Canada in connection with the ecological impact of air and water pollution arising from the thermal generation of electric power, as well as the associated health problems. Furthermore, studies of the dispersion of air pollutants and the complex processes which lead to

the formation, for example, of ozone are also being undertaken.

However, the major issue relating to research and development in thermal generation appears to be that of funding. The R & D programmes in hand at present will probably lead to more effective utilization of fossil fuels in future years - is adequate attention being given to this aspect of long-term electric power planning?

IV. Multi-Purpose Plants

It was mentioned in Issue Paper # 2 that higher efficiency of utilization of primary energy may be achievable by designing multi-purpose plants. Although such plants have been in operation for many years and might therefore be considered as "conventional generation technology", they also fit into the alternate technology category because, on a comparative basis, they are not used widely in Ontario at present. Best known among the various options are plants for the co-generation of electricity and process steam and of electricity and hot water. From the standpoint of energy conservation these systems probably have an important role to play - more useful energy can be obtained from the same amount of fuel. Several industries in Ontario are using this principle notably the pulp and paper, and the chemical industries. But in Sweden, for example, the concept is being implemented much more widely and the combination of electric generation and thermal energy generation for district heating is particularly important. (District heating may be simply defined as the provision of heat from central sources for heating houses, apartments, industrial and commercial buildings within prescribed geographical limits which are determined largely by the power of the central station.)

Several issues relating to multi-purpose plants have been brought to the Commission's attention. They are concerned with first, the possibilities of industrial self-generation, secondly, the potential in Ontario of district heating schemes and thirdly, the use of solid waste as a fuel for thermal generation (see also

the previous section):

- Recognizing that the existing methods for thermal generation of electric power are inefficient largely because the "lost thermal energy" is not being utilized, to what extent are dual-purpose plants, with much higher thermodynamic efficiencies, viable in industry? Do reliable markets exist for such schemes? - For example, could any excess thermal energy and electric power be sold to industrial and domestic customers? What improvement in efficiency could be realized in such circumstances? How many industries and of what type would benefit from co-generation schemes?

- If the electric power system were to become more decentralized, under what terms should energy exchanges occur with Ontario Hydro? If industrial self-generation were to become more widespread would future bulk power transmission requirements decrease? What would be the impact on reliability of such systems?

  It has been suggested that Ontario Hydro might play an important role in future "industrial self-generation schemes". For example, would it be desirable for Ontario Hydro to install and operate such systems in industry and/or obtain the necessary fuels under long-term contractual agreements? It has also been suggested that the combined cycle gas turbine generator may offer unique advantages in a "total energy system". What are the capital implications to the province of such arrangements?

- How viable would district heating schemes, which exist, for example, in Sweden, be in Ontario? It should be borne in mind that district heating necessitates high capital costs and frequently large "front-end costs".

  What institutional and regulatory problems exist with respect to the responsibility for district heating in Ontario and what potential role, if any, would Ontario Hydro play?

  Desirable sites for district heating systems are usually adjacent to urban areas, e.g. new subdivisions, what are the environmental and socio-economic implications? What back-up systems might be required during very cold Ontario winters (such as the present winter)?

  To what extent do potential solar heating and district heating systems conflict insofar as they appear to serve the same market? This appears to be an issue of central significance and extensive studies which take into account

financial, economic, environmental and socio-economic aspects should be taken into account.

- Quite apart from the potential utilization of municipal waste as a fuel for the generation of electricity, other waste materials have high potential in this regard. An example, also introduced in Issue Paper # 2, is the utilization of bark, wood waste and various liquors in the pulp and paper industry as fuels for the co-generation of electricity and process steam or hot water. What is the viability of such waste utilization schemes?

V. Solar Energy

Historically, renewable energy resources, particularly wood and hydro-power, have played a highly significant role in Ontario's development. Wood has been used for residential heating, windmills have been used on farms for pumping water, hydroelectric power has supplied substantial amounts of electrical energy in Ontario. More recently, these renewable energy resources have had to be supplemented on an ever-increasing scale, by the fossil fuels and more recently by nuclear energy. However, the marked increase in the cost of electric power generation using conventional and nuclear fuels, together with the prospect of future shortages as well as environmental concerns have given rise to a resurgence of interest in alternative, renewable energy technologies of which the most significant appear to be solar energy (to produce thermal energy and electricity), wind energy (to produce electric power) and biomass conversion (to produce gaseous and liquid fuels as well as electricity). We devote this section exclusively to solar energy.

To date solar energy has not apparently been exploited extensively, except for special-purpose applications such as the heating of green-houses and the low-level heating of homes, factories, etc. for three major reasons:

- Although solar energy is extremely abundant, its density is low and in consequence its collection and conversion are costly.

- The density of solar energy at any place on earth is variable (e.g. the day-night cycle and the effect

of cloud conditions). This necessitates energy storage capabilities of various capacities.

- Until comparatively recently research and development in solar energy, its collection, conversion, storage and utilization, have been poorly financed and government support has been minimal.

In outlining the major issues relating to solar energy it is convenient to distinguish between solar heating (i.e. of space and water) and the conversion of solar energy into electric energy. Although solar heating does not contribute directly to electric power generation its indirect contributions in this regard could be significant in the future.

(a) Space heating

The potential of solar energy for space heating has captured widespread public attention largely because it is a renewable resource, it suggests a degree of decentralization with associated individual control, and it appeals to the public especially during a period of escalating costs of conventional energy. The concept of solar space and water heating is not new. What is new is the practical demonstration of these technologies. The purpose of these is to test the economic and technical viability of solar energy systems and to provide some of the answers to the following questions:

- What classes of space (and water heating) are best suited to solar energy e.g. single-family homes; multiple family dwellings; town-houses, schools; commercial warehouses, etc.? How viable is the retrofitting of solar energy systems in older homes and structures?

- Present indications are that space heating (and water heating) is more economical for use with multi-family dwellings than for single family homes; to what extent should this factor influence building codes and patterns in the future? Quite apart from the use of special collectors and special installations, should there be increasing emphasis on the design of living and working spaces so that an optimum level of solar energy is captured during the winter months and

rejected during the summer months? Should improved insulation standards and, for example, triple glazing be mandatory for new buildings?

- There are many technical problems relating to the design of solar energy heating systems, such as the design of collectors, heat exchangers, thermal energy storage systems, etc. How can manufacturing industry be encouraged to manufacture solar energy systems? What about the role of universities and colleges in educating and training necessary man-power? Lead times necessary for the production of solar energy systems on a reasonable scale (say, the equipping of ten percent of all new homes and suitable commercial buildings) might be as long as 15 years - can anything be done to shorten this period?

- Electric power and energy pricing policies and structures could have an important influence on the potential of solar energy and on how quickly it becomes a viable alternative energy resource. To what extent should revised electricity pricing policies and structures take into account the need to stimulate the solar energy option?

- What about back-up for solar energy systems equipped, for example, with short-term storage? Reliance on electric power during a period when a yearly maximum peak demand occurs would not relieve the pressures on capital requirements for major generating facilities, what about other forms of back-up such as oil and gas?

(b) Direct conversion to electric energy

It has been well known for more than 100 years that light can generate electricity - the photocell, which has very many uses, is the most familiar example. But the efficiency of photocells is extremely low and their use in order to generate electricity on a massive scale is impracticable. However, with the dramatic developments in semi-conductor devices (which include transistors), and in particular the development of solar cells (usually called photovoltaic cells), in connection with the space programme, the photovoltaic cell is assuming greater significance as a potential generator of electricity on a large scale. The theory of photovoltaic cells is far beyond the scope of this issue paper - an excellent account

is given in "Scientific American", October 1976, pp. 34-43. The major obstacle, at present, to the large-scale development of photovoltaic cells for electric power generation, on a reasonable scale (say 100 kilowatts upwards) is that on a "per kilowatt" basis the capital cost is almost twenty times greater than nuclear power.

An important characteristic of photovoltaic cell technology is that is lends itself to modular construction and hence to economy of scale in the production process - this does not apply to the development of large thermal generating stations. In other words the technology could give rise to some decentralization of the electric power system, albeit on a comparatively small scale e.g. supplying electricity for a supermarket or for a commercial centre, and in this respect it is similar to solar heating. The major issues are:

- What kind and level of storage would be involved in such systems and what "back-up" would be necessary?
- Assuming, by the end of the century, that there is some degree of decentralization of the electric power system predicated in part on solar energy, what are the cost implications?
- What about the lifestyle implications of an increasing measure of decentralization? Would this lead to a greater appreciation of the need for energy conservation?

(c) Future prospects

During the past few years there has been a marked increase in the funding of solar energy research and development and this appears likely to continue. It is particularly noteworthy in the United States where a several-fold increase in funding has been experienced during the past three years. In Canada, in general, and in Ontario in particular, the funding, on a per capita basis, has been at an appreciably lower level.

- In view of the future potential of solar energy for space and water heating and its increasing potential for electric power generation, albeit initially on a very small scale, should the government of Ontario and especially Ontario Hydro initiate a major research and development programme in solar energy?

VI. Other Sources and Technologies

Many potential sources of primary energy for the generation of electric power have been suggested on a global basis. In addition to those which have already been introduced in this issue paper and in Issue Paper # 1 we have noted the following - wind power, tidal power, wave power, biomass power, thermal gradient power in the oceans, fuel cells, and there are probably several others. Several of these are, of course, derived directly from solar energy, e.g. wind power, wave-power, biomass, thermal gradients, etc. Those which may be relevant to Ontario's future electric power system might be wind power and biomass power.

However, there are several other possibilities, either available or in various stages of development, which could be significant in Ontario's future electric power system.* These include the use of heat pumps and, probably on a longer time-scale, which may extend beyond the end of this century, nuclear fusion power and magneto-hydrodynamics. Brief notes on these possibilities follow:

(a) Heat pumps

The principle of the heat pump has been known for many years. In effect, a heat pump operates on the same general principle as the domestic refrigerator. Buring the summer months, for example, a heat pump can operate as an air-conditioner.

During the winter months a heat pump extracts heat from a large space (this is always low quality thermal energy) and injects the thermal energy into the space to be heated. If the ambient temperature is in the range of

*In this paper we have not introduced the issue of the importation (or exportation) of electric power from (or to) neighbouring utilities - a subsequent issue paper (probably #7) will introduce this question.

about -4°C to about 16°C, commercially available heat pumps can improve the efficiency of an electric power supply by at least 50%. However, a heat pump, particularly suitable for winter conditions in Ontario, could be designed which would operate with appreciably lower ambient temperatures and provide acceptable "gains" in efficiency. Obviously, capital is required to purchase and install heat-pumps but on a long term basis (say 5-10 years), because of savings in electric energy utilization, the system would be economically viable. To what extent should Ontario Hydro encourage developments in heat-pumps and especially developments leading to lower cost systems? - Ontario Hydro is in fact, undertaking basic research in the design of heat pumps.

(b) Biomass energy

Man's traditional fuels, apart from wind energy and other forms of solar energy, have been produced, directly or indirectly, by photosynthesis. The most important example is, of course, the burning of wood. It is not surprising, therefore, that there has recently been a resurgence of interest in biomass energy i.e. the generation of fuels by growing, harvesting and burning plants and trees.

Because of the inconvenience of storing wood on a massive scale and even the waste products of the pulp and paper industry (although these will be used increasingly to generate thermal energy), recent developments in the utilization of biomass are concerned with the conversion of the raw material into highly refined products. It has been pointed out, for example, that wood can be converted into various forms of alcohol, notably methanol, which are excellent liquid fuels. Furthermore, municipal waste can be converted to a fuel gas which contains hydrogen and carbon monoxide, and which can substitute for

natural gas, or alternatively it may be converted to methanol which has been used effectively as a gasoline additive. There is clearly a considerable range of possibilities. To what extent should the Ontario Government and Ontario Hydro be undertaking research and development into the potential of biomass energy in electric power generation?

(c) Wind power

During the hearings there were many references to the potential of wind energy generators for the generation of electricity. During the past year the Commission has received information from the National Research Council, from a Canadian-based firm engaged in the production of wind generators, from the Commission's Symposia - a paper was devoted to wind energy and from several participants during the Public Information Hearings. This information is available in the Commission's Information Centre.

At present the consensus appears to be that, with the possible exception of certain locations in Northern Ontario, the scope for wind energy in Ontario is not particularly appropriate because the average wind velocities in most locations are below those regarded as marginal for the extensive use of this source of energy. Nevertheless, research and development programmes are being continued and the Commission is in close touch with developments. Should Ontario Hydro undertake research or sponsor research in wind energy and its potential in electric power production?

(d) Fusion power

During most of its lifetime of a few billion years, a star, including the sun, will generate heat at its centre by converting hydrogen into helium. The process of the fusing together of the nucleii of light elements, especially hydrogen, and the concomitant release of energy because of a minute loss of mass is referred to as nuclear fusion energy. Large-scale research programmes in the fusion energy field

are being undertaken in many countries notably the United States and the Soviet Union, and the fusion process has been demonstrated in several laboratories, albeit on a microscopic scale both in time and space.

The engineering problems involved (the scientific basis for the process is now understood) are very complex especially insofar as the development of suitable materials is concerned. This is not surprising when it is realized that maintenance of the nuclear fusion reaction involves plasma temperatures in the order of 50-100,000,000°C. A discussion of this highly sophisticated, but nevertheless extremely significant development, is far beyond the scope of this issue paper. On the other hand, since fusion energy and solar energy may become, during the 21st century, the basis of all energy production on earth, and because of the potential "environmental purity" of both fusion and solar power, an awareness, by the public, of the availability of these techniques is important. To what extent should research and development in fusion energy be undertaken or supported by Ontario Hydro?

(e) Magneto-hydrodynamics

The search for a method of converting directly the thermal energy of combustion of fossil fuels and nuclear fuels into electrical energy has been actively undertaken for many years. The major objective is to eliminate the massive energy losses which are associated with the conventional use of the so-called "steam cycle" in which steam turbines are the central component. For reasons given in section I the inherent energy losses in the conventional process may amount to 60%, or even more, of the potential energy of the primary fuels.

One method of attacking this problem is the so-called magneto-hydrodynamic technique through which some of the kinetic energy in a high velocity stream of hot gas (e.g.

as generated in an aircraft jet engine), is converted directly into electric energy - the thermal energy in the gas may subsequently be converted into electricity by conventional means. Commercial implementation of the technique is already well advanced in the Soviet Union where generating stations of powers up to 100 MW have been operated successfully.

It has been demonstrated, theoretically, by one Ontario professional engineer, with high qualifications in this field, that, combined with an adequate level of nuclear power production, and together with the "hydrogen technology" referred to previously, magneto-hydrodynamic systems might play a significant role in the future in Ontario's electric power system. Apparently the most significant remaining problems relate to the development of materials which will withstand the very high temperatures and the corrosive effects of the high velocity gas jet streams. In view of the appreciably higher thermodynamic efficiency achievable by using magneto-hydrodynamic techniques, and the long-term potential of those methods, would it be justifiable for Ontario Hydro to sponsor research in this field?

Postscript

The above alternative energy sources were brought to the attention of the Commission during the preliminary meetings and the information hearings. In the case of nuclear fusion energy an independent study, the results of which will be available shortly, has been commissioned. The intention is to obtain an assessment of the present "state of the art". In the cases of the other alternatives, as mentioned previously, a considerable amount of information is available in the Commission's Information Centre.

APPENDICES

Appendices A, B, and C provide a sample of the comments relating to the Conventional and Alternate Generation Technologies which were made during the preliminary public meetings and the public information hearings, together with references to the subject in the research and background papers prepared for the Commission. Appendix D gives firstly, some data concerning the 1976 generating facilities of Ontario and secondly, some data on fuel requirements including "energy equivalents" (e.g., how much coal, or oil, or uranium is required to produce one unit of electricity, etc.).

More detailed information on Conventional and Alternate Generation Technologies is contained in the transcripts, memoranda for public viewing in the Commission's Information Centre, 14 Carlton St., Toronto, Ontario, M5B 1K5 and in the Regional Depositories located in the Main Libraries in Thunder Bay, Sudbury, London and Ottawa. The research documents are only available at the Commission's Information Centre in Toronto.

APPENDIX A

REFERENCES TO CONVENTIONAL AND ALTERNATE POWER GENERATION TECHNOLOGY AT THE PRELIMINARY HEARING

I. HYDRAULIC

"I wish to propose to resurrect an interest in small hydro-electric power generation stations in the 5-100 MW capacity ranges throughout the provinces to embark on a systematic construction program to harness all remaining undeveloped sites." S 61

"The time for damming rivers, spoiling our environment and wasting our energy should belong to the past and more imaginative ways pioneered." S183

"Hydro-electric power should be exploited. This form of power is not going to pollute the land other than the aesthetic value will be diminished by the transmission lines. There will be minimal water pollution as well as no air pollution." S340

II. THERMAL

"Oil, natural gas and coal are fast running out as a cheap energy source." S 4

"Nevertheless, the resources are finite, and eventually be depleted. That is why the oil companies are given depletion allowances." S 5

"How important in the analysis is the fact that a large part of Ontario's electricity is generated from coal imported from the United States?" S100

"Require Ontario Hydro to discontinue burning over 49 billion cubic feet of natural gas each year to recover only 30% of its energy when home space and hot water heaters could recover 70%." S161

"Generating plants using fossil fuels should be equipped with stacks containing scrubbers and the most up to date pollution abatement equipment. The abatement programme must be up-dated as techniques are advanced." S181

II. THERMAL (Cont'd)

"At an 800 MW fossil plant near Quetico Park, every day 220 tons of sulphur dioxide will be emptied along with 2-1/2 lbs. of mercury -- spread wherever the air carries it." S174

"Ontario Hydro has followed stringent practices in the past in controlling some pollutants, particularly particulates. The same degree of concern should also be shown for sulphur dioxide, oxides of nitrogen, radioactive wastes, and heat discharge. Specific economic incentives should be established to encourage the development of abatement technology such as imputed prices for pollutants that are discharged. Otherwise the growth of pollutant emission will be intolerable." S 58

"A natural gas system seems the least destructive of the systems presently used in Ontario to produce electricity." S180

"The association suggests the failure to control fuel costs, an item which accounts for the bulk rate increase in 1976, is the result of long-range planning at Ontario Hydro. Agreeably, it is also the result of the lack of incentive to control fuel costs." S105

"How long will American coal be available and at what Price?" S182

III. MULTI-PURPOSE PLANTS

"It will soon become even more imperative in the future to improve on the utilization of resources and to reduce the potential for thermal pollution from electric power plants. Combined-purpose thermal power plants are an effective means of accomplishing these goals." S 99

"What are the monetary, social and energy costs and benefits of centralized versus decentralized power production to the people of Ontario ?" S 89

"We recommend that electric utilities should be made responsible whenever possible for the optimum use of fuel by the combined production of electricity and heat and that governments establish mechanisms to ensure that this objective can be accomplished." S 90

III. MULTI-PURPOSE PLANTS (Cont'd)

"I would recommend to the Commission that they study the contribution which combined heat and power plants could make to overall energy conservation. I would further recommend that consideration be given to changing the terms of reference for Ontario Hydro so that they are responsible for providing total energy (i.e., space heating and electric power), to consumers at the lowest possible cost." S 66

IV. SOLAR

"How serious and committed has the search to date of alternative power sources been?" S 60

"Research is needed into alternate sources." S 1

"Ontario Hydro should be actively involved in development of a solar energy system supplying the equipment on a purchase or lease basis to homeowners and apartment building owners." S111

"Consider using solar and/or wind power for individual or small groupings of residential, commercial or industrial developments as an alternative to large generating plants and long transmission lines." S195

"The pollution from fossil fuels is killing and disabling people, and the permanent legacy of environmental destruction is occurring from coal mining. The Hydro-electric projects inalterably destroy our fisheries, wildlife, agricultural land, scenic resources and human cultures, and thus eliminate future generations right to use the land differently." S 33

"While we would support the expenditure of reasonable sums on research and development of new generation technologies employing such sources as solar, geothermal, wind, etc., we do not see these as being a practical alternative to the present sources until after the turn of the century." S208

V. <u>OTHER SOURCES</u>

"Close proximity to Manitoba ought to suggest co-operation in electric power developments, including joint financing, and east-west power transfer." S177

"Significant economics may be achieved from planned power pooling between the provinces of Canada." S103

"The development of our CANHO-MHD Electricity Storage System and its subsequent installation in multiple units into the Ontario Hydro Generating System during the 1983-1993 expansion period, would make a major reduction in the cost of generating electricity within the Province of Ontario." S 67

"Fusion provides the possibility of a total and permanent energy solution." S380

"The use of fuel cells implies a decentralization and dispersion of the sources of electrical energy which must be co-ordinated with the need to maintain large efficient centres of generation and effective systems for transmission and distribution." S209

APPENDIX B

REFERENCES TO CONVENTIONAL AND ALTERNATE POWER GENERATION TECHNOLOGY MADE DURING THE PUBLIC INFORMATION HEARINGS

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APPENDIX B-2

REFERENCES TO CONVENTIONAL

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REFERENCES TO CONVENTIONAL AND ALTERNATE POWER TECHNOLOGIES IN OTHER SUBMISSIONS AT THE PUBLIC INFORMATION HEARINGS

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LIST OF EXHIBITS

Topic 2: Generation Technical

Exhibit 2-4	Summary of the Undeveloped Hydraulic Power Resources of Ontario.

Topic 3: Generation Environmental

Exhibit 3-6	Arsenical Air Pollution and Lung Cancer. An article by William J. Blot and Joseph F. Fraumeni, Jr., The Lancet, July 26, 1975, p.142.
3-7	Prefiled Testimony of Dr. William N. Stasiuk before the New York Public Service Commission, dated October 1, 1975, docket numbers PSC 26529 and 26559
3-8	Environmental Design Manual (to come)
3-9	Ontario Hydro Research Quarterly Bulletin #23, No. 2, Second Quarter 1971, by Kerry "SO_2 Near Generating Stations."
3-10	Suspended Particulates from Fossil Fuels
3-11	Article entitled "The Findings Got Changed", Los Angeles Times, February 29, 1976

Topic 8: Provincial Development and Land Use Planning

Exhibit 8-6	Main components of Provincial Planning System

Topic 9: Ministry of Agriculture and Food

Exhibit 9-2	A Policy Position Paper entitled "Strategy for Ontario Farmland"

Topic 12: Ministry of the Environment

Exhibit 12-5	Letter, December 17, 1969, from G.E. Collins, Chairman, O.W.R.C. to G.E. Gathercole, Chairman of Ontario Hydro
12-6	Technical Guidance Manual for Water Drainage P.L. 316, U.S. Zero Discharge, "Requirements for Cooling Towers"

12-7	Air Quality Monitoring - Reports for 1971-12-7 (a) 1972-12-7 (b) 1973-12-7 (c)
12-8	Report re Sulphur Dioxide Review (to be filed)
12-9	Emission Survey for Metropolitan Toronto (Hearn and Lakeview)
12-10	Report on Oxidants and their Precursors in Canada (to be sent to O.H.)
12-16	Environment Canada: Review of Heated Discharge for D. of E., Management and Control Alternatives Once-through Systems in Large Water Bodies, Economic and Technical Review Report EPS 3W.P.-4
12-17	Exchange of letters re the Lake Huron Thermal Plants in the vicinity of Bruce (to come)

Topic 13: Ministry of Energy

Exhibit 13-1	Wind-power report prepared for the Ministry of Energy and Ontario Hydro by the Ontario Research Foundation and the Electrical Research Association of the United Kingdom
13-2	Report entitled Preliminary Assessment of the Potential for Large Wind Generators for Fuel Savers in AC Community Diesel Power Systems in Ontario, dated March 12, 1976, prepared by the Ontario Research Foundation, C.K. Brown in conjunction with Dr. R. Higgin
13-3	District Heating Study dated February 1976 carried out by Acres Shawinigan Ltd., for the Ministry of Energy
13-9	Paper to be delivered by Dr. Roger Higgin at the Winnipeg Solar Energy Conference (to be supplied)

Topic 14: Ministry of Natural Resources

14-2	An extract from Working Group Project 23, Upper Lake Working Group, International Joint Commission

Topic 15: Project Management

Exhibit 15-6	Letter from R.B. Taylor To A. C. MacDonald and attachments

Topic 17: Fuels Supply

Exhibit 17-2	Group of Transparencies respecting Fuel Supply, 8 in all
17-3	Chart from p.76 of the 1973 Report of the Federal Department of Energy, Mines and Resources, "An Energy Policy for Canada"
17-4	Figure 20 taken from page 83, Canadian Energy Prospects
17-5	Chart 19 from the Ministry of Energy presentation to the Select Committee

Topic 23: System Interconnections

Exhibit 23-10	Review of Consultants Report on the Social Effects of Atmospheric Emissions from Fossil-Fired Thermal Stations, Report 75-75-K, prepared by P.J. Youston, Mathematician, Ontario Hydro, Operations Research Group

Topic 32: Fisheries and Environment Canada

Exhibit 32-1	Pamphlet issued by International Joint Commission, 1974 entitled Great Lakes Water Quality
32-2	International Joint Commission, 1975 - Annual Report regarding Great Lakes Water Quality
32-3	Paper entitled Long Distance Transport of Atmospheric Pollutants
32-4	Pamphlet entitled The Clean Air Act - Regulations and Guidelines
32-5	Agreement respecting Great Lakes Quality between Her Majesty the Queen in right of Canada and Her Majesty the Queen in right of Ontario, dated March 12, 1976
32-6	Summary of Brief presented by Dr. R. W. Slater

Topic 37: Ontario Institute of Agrologists

Exhibit 37-1	Norman Pearson's Study - "Foodland and Energy Planning" Volumes I and II

Topic 38: Energy Probe

Exhibit 38-2	Document entitled The Renewable Energy Handbook
38-3	Paper entitled Projecting an Energy Efficient California by Goldstein and Rosenfeldt
38-5	Booklet reprint from Foreign Affairs entitled Energy Strategy: The Road Not Taken? by Amory B. Lovins

Topic 44: The Ontario Electric League

Exhibit 44-1	See attached list

Energy and Mans Environment Incorporated

1) Energy Activity Guide
2) Glossary
3) Sources of Energy
4) Uses of Energy
5) Conversion of Energy
6) Impacts of Energy
7) Limits of Energy
8) Future Sources of Energy

Topic 46: Huron Power Plant Committee

Exhibit 46-1	Document entitled Highlights from Ormrod Study on Air Pollution in Huron County, 1976
46-2	Document entitled Air Pollution Studies, Huron County 1976, D.P. Ormrod
46-3	Document entitled the Impact of Urban and Industrial Development on Crop Production in Surrounding Areas by D. P. Ormrod

Topic 53: Science Council of Canada

Exhibit 53-2	Science Council of Canada, Report #23 dated March 1975 entitled Canada's Energy Opportunities
53-3	Science Council of Canada, Report #25 dated July 1976 entitled Population, Technology and Resources

Topic 59: The Canadian Steel Industries Construction Council

Exhibit 59-2	Remarks by Robert F. Gilkeson, Chairman of the Board, Philadelphia Electric Company, made before the American Institute of Steel Construction dated October 30, 1974 "Electric Power and American Industry-A Look Ahead"

Topic 61: Ontario Mining Association

Exhibit 61-1	Resumé or list of Power Interruptions in Mines in Ontario (to be received)

Topic 64: Office of Energy Conservation, Energy Mines and Resources, Canada

Exhibit 64-6	Booklet entitled A Critique of "At Issues: Electricity" November 1976.

APPENDIX C

RESEARCH AND BACKGROUND PAPERS DEVELOPED BY THE COMMISSION

Environmental Health Factors Associated with Power Generation	Dr. D. Dewees
Fuels - The Supply and Demand	Dr. L. Bertin
Power Generation Technologies - The Alternative	Dr. R. Swartman
Socio-Economic and Institutional Factors in Electric Power Planning	Dr. C. Hooker
A Study of Awareness, Attitudes and Future Expectations of Ontario Residents Regarding the Supply and Use of Electrical Energy	Semper Paratus Ltd.
Land Use Implications of Electrical Supply Facilities	Norman Pearson
The Role of Ontario Hydro as an Economic Development Tool of the Province	J. O. Dean
A Methodology for Comparing Total Costs of Alternate Technologies in Electrical Supply	Dr. Philip Hill
An Impact Survey of Communities Adjacent to Recent Ontario Hydro Developments	Dr. E. Pickett (Experience '76 Project)
A Survey of the Prospects of Solar Electricity and Heating for Ontario	Dr. J. Shewchun
An Evaluation of Possible Solar Energy Market Share for Space and Water Heating in Ontario	I.B.I. Group Ltd.

RESEARCH WORK FUNDED BY THE COMMISSION

Food Land Steering Committee

Research includes:

- future food and energy needs
- impact of large generating stations and transmission lines

Huron Power Plant Committee

Research includes:

- damage to crops by industry induced air pollution
- relationship between ozone concentrations and weather patterns.

Energy Probe - Toronto

Research includes:

- the economic, environmental and social implications of Ontario Hydro's generation programs as compared to other alternatives.

Conservation Council of Ontario

Research includes:

- areas of conservation and pollution, use of waste heat from generating stations,
- alternative sources of generation, merits of the use of more coal and less gas and oil as fuels, potential of solid waste as fuel,
- pricing, improvements in building codes, land use, etc.

Sierra Club

Research includes:

- study on potential for energy conservation in Ontario
- study on estimated effect on peak load of electric hot water heating and electric space heating.

APPENDIX D

DATA CONCERNING THE 1976 ONTARIO HYDRO SYSTEM

Station Type	No. of Stations	Total Capacity MW	%	Energy Production %
Hydro-electric	72	6,200	30	36.0
Coal	4	8,100	40	24.0
Oil	1	1,500	7	2.9
Gas	1	600	3	4.6
Nuclear	3	2,300	11	17.0
Combustion Turbine	13	460	2	0.0
Purchases	5[‡]	1,200	6	15.5
Total	99	20,360	99	100.0

The load factor during 1976 was 65%.

‡ This represents a count of the possible sources of purchased electricity.

* One Megawatt (MW) is 1 million watts.

FUEL REQUIREMENTS DATA

Energy from a variety of different fuels can be used to produce electricity. The following chart shows the amount of fuel consumed in the production of a stated amount of electricity using each of six primary 'fuel' types.

Fuel Type

	Coal		Oil		Natural Gas		Nuclear (Uranium)		Solar Energy*
Fuel consumed to produce 1 Megawatt Hour (MWHr)	.36 tons (720 lbs.)	or	66 Imp.Gals. (1.8 barrels)	or	10,000 Cubic Feet	or	22 grams (.05 lbs.)	or	5 Sq. Meters (53 Sq. Ft.)
Fuel required by Ontario Hydro to produce the annual electricity requirements of the average Ontario household (9.8 MWHr)	3.6 tons	or	660 Imp.Gals. (18 barrels)	or	100,000 Cubic Feet	or	220 grams	or	50 Sq. Meters

* These figures represent the collector space (angled towards the sun) required to produce the required amount of electricity over a period of one year.

FUEL CONSUMPTION IN ONTARIO

	Coal	Oil	Natural Gas	Nuclear (Uranium)	Other (Hydro Purchased Electricity)
Actual 1976 Ontario Hydro Fuel Usage - Expressed in Fuel Units	8,400,000 tons	4,500,000 barrels	50.0 billion Cubic Feet	380 tons	-
- Expressed in Energy Units (British Thermal Units)*	220×10^{12} BTU	26×10^{12} BTU	42×10^{12} BTU	150×10^{12} BTU	160×10^{12} BTU
Actual 1974 Ontario Fuel Usage (for all energy requirements, NOT just electricity)	360×10^{12} BTU	$1{,}100 \times 10^{12}$ BTU	690×10^{12} BTU	140×10^{12} BTU	160×10^{12} BTU

* Since both kilowatt hours (KWHr) and British Thermal Units (BTU) are energy units they are related by definition (1 KWHr = 3412 BTU). However, in considering Ontario Hydro's use of fuel to produce electricity, it must be realized that conversion, using present day generation technology, occurs at approximately 30% efficiency. For this reason, the production of one kilowatt hour of electricity consumes 10,000 BTU of primary energy resources.